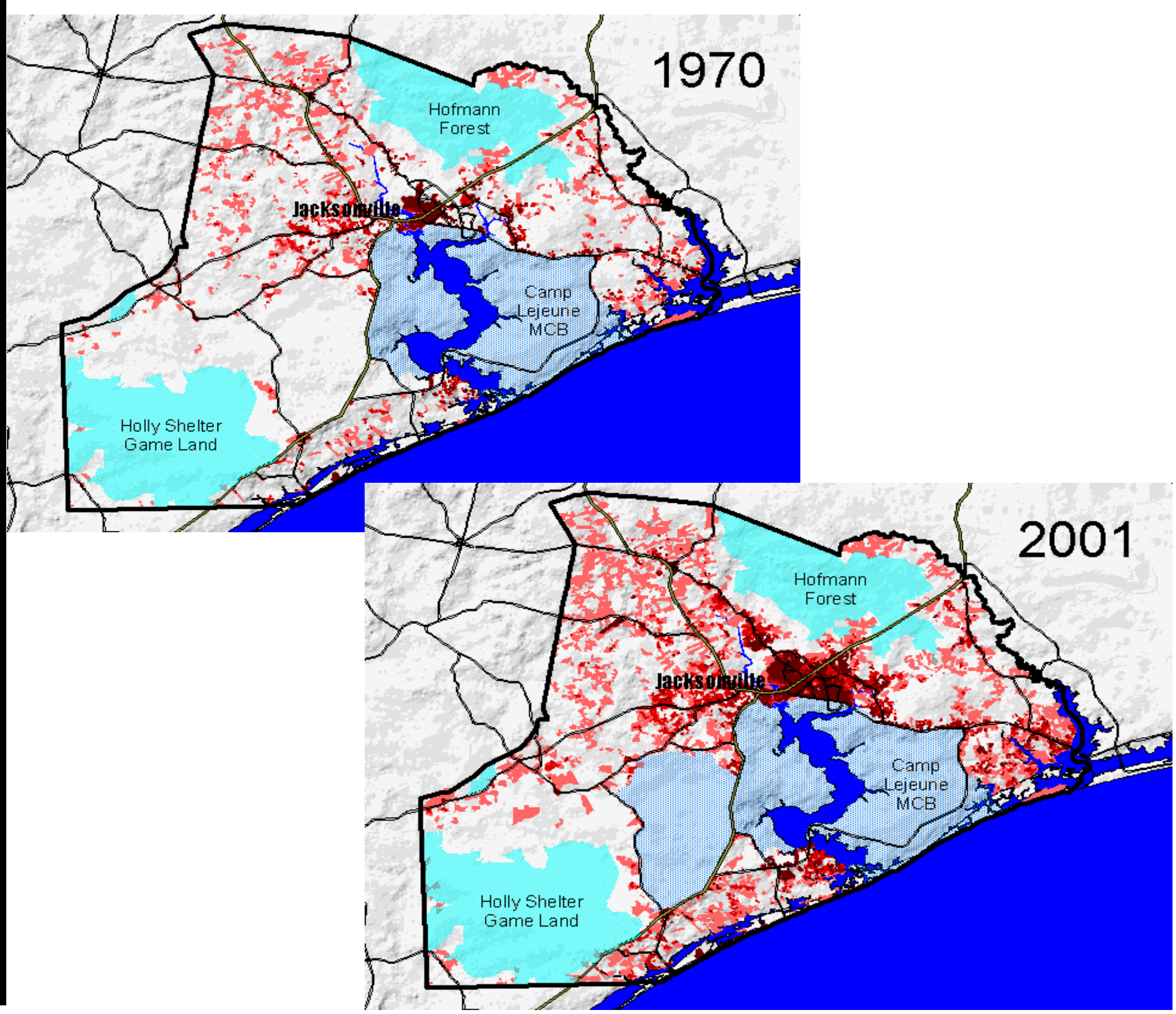
ERDC/CERL TR-03-9

US Army Corps of Engineers®
Engineer Research and Development Center

A Geographic Information Systems (GIS) and Imagery Approach to Historical Urban Growth Trends Around Military Installations

Robert C. Lozar, C.R. Ehlschlaeger,
and Jennifer Cox

May 2003



ERDC/CERL TR-03-9
May 2003

A Geographic Information Systems (GIS) and Imagery Approach to Historical Urban Growth Trends Around Military Installations

Robert C. Lozar

U.S. Army Engineer Research and Development Center
Construction Engineering Research Laboratory
Champaign, IL 61826-9005

C.R. Ehlschlaeger and Jennifer Cox

Department of Geography
Hunter College
City University of New York
New York, NY 10021

Prepared for U.S. Army Corps of Engineers
Washington, DC 20314-1000

Under Contract DACA42-01-P-0213

Abstract: Recent advances in computer analysis techniques based on remotely sensed satellite images can be used with other geographic information systems (GIS) data to establish a scientifically derived baseline of growth near military installations. Developing such a trend analysis is one step in support of a military initiative to identify and mitigate pressure on its military mission activities due to the development or placement of land uses near installation boundaries. The new land uses, often described as "encroachment," may in some way conflict with the ongoing activities at an installation. This study documents a unique procedure called "CellPicker" to generate land cover changes using satellite images and contextual GIS data for the each decade beginning in the 1970s.

Contents

List of Figures and Tables

Figures

Table

Preface

This study was conducted for U.S. Army Corps of Engineers under project number 622720A896, “Base Facilities Environmental Quality”; PROMIS number CNN-DKK777, “Quick Encroachment System.” The technical reviewers were William D. Goran and Dr. William D. Severinghaus, Construction Engineering Research Laboratory (CERL).

The work was performed by the Ecological Processes Branch (CN-N) of the Installations Division (CN), CERL. The CERL Principal Investigator was Robert C. Lozar. Dr. Charles R. Ehlschlaeger is a professor in the Department of Geography, Hunter College, City University of New York (CUNY). Jennifer Cox was a graduate student at CUNY. Part of this work was done under Contract DACA42-01-P-0213. The technical editor was Linda L. Wheatley, Information Technology Laboratory — Champaign. Stephen Hodapp is Chief, CN-N, and Dr. John Bandy is Chief, CN. William D. Goran is the associated Technical Director. The Director of CERL is Dr. Alan W. Moore.

CERL is an element of the U.S. Army Engineer Research and Development Center (ERDC), U.S. Army Corps of Engineers. The Commander and Executive Director of ERDC is COL John W. Morris III, EN, and the Director of ERDC is Dr. James R. Houston.

1 Introduction

Background

Recent advances in computer analysis techniques based on remotely sensed satellite images can be used with other geographic information systems (GIS) data to establish a scientifically derived baseline of growth near military installations. This work is in support of a military initiative to identify and mitigate pressure on its military mission activities due to the development or placement of land uses near the installation boundaries. The new land uses, often described as “encroachment,” may in some way conflict with the ongoing activities at an installation. Military installations are increasingly asked to alter activities within their boundaries to alleviate encroachment conflicts. Examples include restrictions on flight routes and firing ranges, and problems with night maneuvers at numerous installations because of “light pollution” from nearby developed areas.

To deal with these issues effectively, an installation planner needs to establish two “trajectories of change”:

1. Establish clearly the urban growth trends in areas surrounding a military installation

2. Provide intelligently based projections of future growth and change.

In this way both military and civilian planners can cooperate in anticipating and devising appropriate strategies to avoid or otherwise deal with potential conflicts before they occur. Problem avoidance is usually much less expensive and more effective than mitigation after the fact.

The concept of following the trend of urbanization within a region and the prediction of how that might continue into the future has been developing for several decades (Steinitz 1967). The U.S. Army Engineer Research and Development Center, Construction Engineering Research Laboratory (ERDC/CERL), Champaign, IL, has engaged in several research projects investigating risk assessments from increased development near installations. The conceptual framework for the approach has been investigated (Rose et al. 2000). Some regions that include military installations have been studied for the alternatives that are available to policy managers

(Steinitz et al. 1996). This has helped to formulate the establishment of a military-specific predictive tool (Deal 2001) for the evaluation of future alternatives.

As a basis for studies that purport to predict the future, it is a good idea to have a clear sense of what has happened in the past. One approach developed at ERDC/CERL is an installation-specific historical urban growth series (Timlin et al. 2002). A historical urban growth series is a set of cartographic illustrations that depict the changes in land use around an installation (Figure 1). Each series consists of several snapshots of the physical environment of an installation and its surrounding region. Presented one after another, this series is a powerful tool for showing the changing conditions around an installation. Though the images are compelling, particularly when presented as an animation, they do not accurately depict urban growth patterns. A drive down the street of an area under development will present a patchy appearance of recently developed locations conspicuously alternating with open fields or forested acreage. Further, the problems and difficulties inherent in developing these graphics may include lack of information, lack of comparability of data from different times, long lapses in the availability of data, different scales, combining sources that are illustrating different concerns, developments that shrink or even disappear between time steps, and data sources that conflict with others and even within themselves. In this situation, though the graphics are compelling, they might not stand up to detailed scrutiny and criticism. It thus becomes an important issue to develop a firm scientific and technical footing to describe objectively how the land uses are really changing over time.

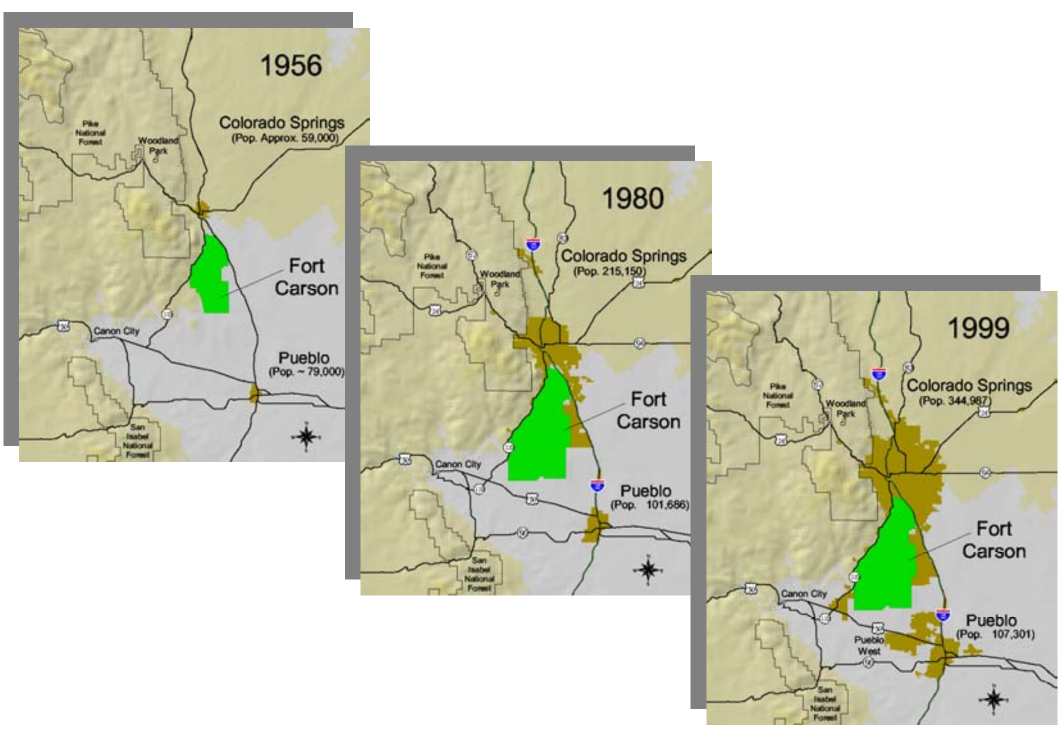


Figure 1. Development growth near Fort Carson, CO.

In an effort to provide an objective approach to a comprehensive encroachment analysis, a procedure was developed to establish the historical urban growth (point 1 above) in areas surrounding installations. Besides identifying historical changes from old maps and aerial photography, a procedure developed by CERL's academic partners at Hunter College (City University of New York, CUNY) was applied to determine land use changes from satellite imagery. This procedure (called "CellPicker") was originally developed on the nearby Sandhills Ecoregion, but the first application for encroachment issues was for the region surrounding Camp Lejeune, NC. The intent was to objectively identify subcategories of urban development (e.g., low and high density development per the U.S. Geological Survey [USGS] standard Land Cover categories). These subcategories will more precisely identify changes in land uses that have potential encroachment conflicts with the military missions at installations. Through this technique, it will be easier to coordinate a historical change study with growth projections the installation might wish to generate. The final product of the Camp Lejeune application was a set of graphics showing land use change from an enhanced, technologically justifiable basis.

Objective

The objective of this research was to document and explicitly describe the steps and procedures required in the preparation of a set of digital and graphic materials to establish the urban growth trends in areas surrounding military installations using the latest scientific procedures.

Scope

This study documented the procedure to generate land cover changes using satellite images and contextual GIS data for each decade beginning with the 1970s. This report is intended to be a guide in carrying out similar regional analyses. The procedure itself has limitations that are discussed in Chapter 6. The procedure described here is not intended to "stand alone," as it also requires cooperation of local governmental entities. In some cases, the procedure described will fall back on more traditional sources of data (e.g., old paper maps) when the needed resources are not available.

This study deals only with land use changes, with specific emphasis on residential and urbanization trends (point 1 in the **Background**). After completing a historical trend analysis, the next logical step is to provide intelligently based projections of future change. This is the subject of other ongoing CERL research not covered here.

Further, this report does not directly deal with the results of generating a historical trend series nor how those results can be used to objectively evaluate the degree of encroachment on the military mission of an installation. However, a technical report (Lozar 2003) specifically for Marine Corps Base (MCB) Camp Lejeune, will illustrate installation-specific applications directly.

Since the first of the Landsat satellites was launched in 1972, a historical trend series based solely on the procedure described here cannot begin earlier than 1972. Further, this procedure deals only with multi-spectral Landsat images. It is possible to extend the satellite baseline back a further decade using Corona panchromatic (i.e., black and white) images as has been suggested in other reports (Lozar et al. 2001b), or even further by using aerial photographs dating as far back as the 1930s. For high-resolution panchromatic images, pattern recognition is required rather than the spectral recognition that is the basis of this report. There is a further gap in the timeline for most installations because many installations were established near the beginning of a major conflict, particularly World War II. The description here cannot fill that gap so other techniques must be used (Timlin 2002; Lozar et al. 2001a). Most of the "encroachment" issues for the military have emerged in the last few decades, however, and this is the period for which the satellite imagery is available.

This technical report uses the MCB Camp Lejeune region in North Carolina as an illustration. Resources that were available for this study region are likely, but not guaranteed, to be available at other locations. The procedure here may be unique due to the resources and data available and the cooperation of the local governmental agencies. In general, however, the procedure should be applicable to other areas.

Mode of Technology Transfer

This report is intended as a milepost in the road to better land management practices and is expected to encourage similar activities and research presentations and papers for applications at other military installations. This report will be made accessible through the World Wide Web (WWW) at: http://www.cecer.army.mil.

2 Ingredients for the CellPicker Soup

To successfully complete the process described here, data from various sources must be incorporated and manipulated. This integration is called the CellPicker soup.

Previous efforts (Timlin 2002) have taken approaches that are enhanced by technology but rely largely on paper maps. The procedure and components described in this report completely depend on the application and manipulation of advanced computer technologies such as (1) Image Processing (IP) of remotely sensed images, (2) the manipulation of spatially reference data within the framework of a GIS, and (3) the use of commands within a computer scripting language to evaluate the data. The IP used here is the ERDAS software package Imagine (Version 8.4 or later), the GIS is ArcView (Version 3.2 or later and/or ArcInfo), and the scripting language is within the Java Runtime Environment (Version 2.0 or later). This report assumes the reader is reasonably familiar with the concepts behind these technologies and that s/he is ready to use them.

Several advances have occurred that now make possible a more defensible illustration of developmental growth. Significantly, data are much more standardized, so the sharing and manipulation of data are more easily accomplished. The integration of remote sensing (RS) techniques into a single coordinated GIS framework is critical. In this project, two sources of data have become the backbone: National Land Cover Data (NLCD) and North American Landscape Characterization (NALC). Since the Landsat satellites began taking images of the earth's surface in 1972, USGS and the U.S. Environmental Protection Agency (EPA) have generated a three-decade series of images (called the NALC Triplicates) for the 1970s, 1980s, and 1990s at 60-m resolution. Another program generated the NLCD at 30-m resolution for the early 1990s.

NLCD: One of the projects sponsored by the Multi-Resolution Land Characteristics Consortium (MRLC) was production of land-cover data derived from images acquired by the Landsat Thematic Mapper (TM) sensor, as well as a number of ancillary data sources. The escalating costs of acquiring satellite images prompted several Federal agencies to agree in 1992 to operate as a consortium in order to acquire satellite-based remotely sensed data for their environmental monitoring programs. Original members of the MRLC were the USGS, U.S. Environmental Protection Agency (EPA), National Oceanic and Atmospheric Administration (NOAA), and the

U.S. Forest Service (USFS). Joining the consortium later were the National Aeronautics and Space Administration (NASA) and the Bureau of Land Management (BLM).

The NLCD includes the source images, as well as classified land-cover data for specific acquisition dates. It is the first national land-cover data set produced since the early 1970s, effectively replacing older data sets. Data for the conterminous United States circa 1992 (1992 NLCD), which were derived from Landsat-5 TM images (Figure 2), are complete and currently available for download. A description of the data and the classification process has been published in a number of journal articles (Kelly and White 1993; Cowardin et al. 1979; Vogelmann et al. 1998a,b).

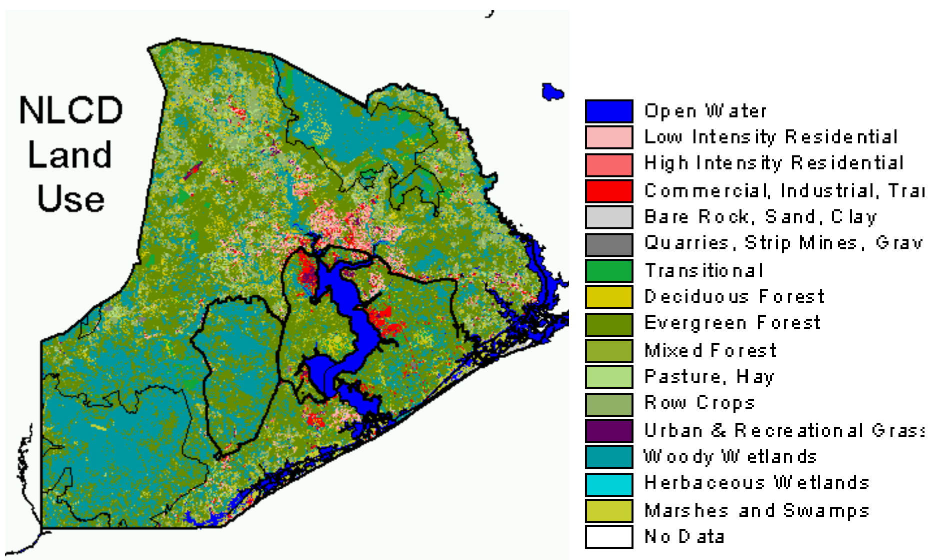


Figure 2. Land use for the early 1990s as presented in the NLCD.

NALC: The NALC project was a collaborative effort between the EPA and the USGS to provide complete coverage of the conterminous United States and Mexico for the purposes of mapping land cover and land cover change. The NALC project includes Landsat MultiSpectral scanner (MSS) data acquired in 1973, 1986, and 1991, plus or minus 1 year, with geographic coverage including the conterminous United States and Mexico (Figure 3). The specific temporal windows vary for geographic regions based on the seasonal characteristics of the vegetation cover. The NALC triplicate scenes are geographically referenced to a 60- by 60-meter Universal Transverse Mercator (UTM) ground coordinate grid. The NALC project is under NASA's Landsat Pathfinder Program.

It was the purpose of this research to combine these data sources to generate a scientifically justifiable set of graphics showing how land use changes have occurred over time. In a series of CERL development contracts, CUNY developed a unique

procedure to use the NLCD as base data to derive historical land cover maps from the images in the NALC data. This is the CellPicker process referred to earlier. It consists of a series of steps using a suite of image-processing GIS manipulations and Java scripts to generate land cover maps for the 1970s, 1980s, and 1990s. The latest version was used to generate map coverage for the entire Sandhills Ecoregion in the Southeastern United States. Chapter 3 describes the procedure in detail. For purposes of encroachment studies the procedure was first applied to the region surrounding Camp Lejeune. Steps described in the next chapter use the Camp Lejeune study area for illustration.

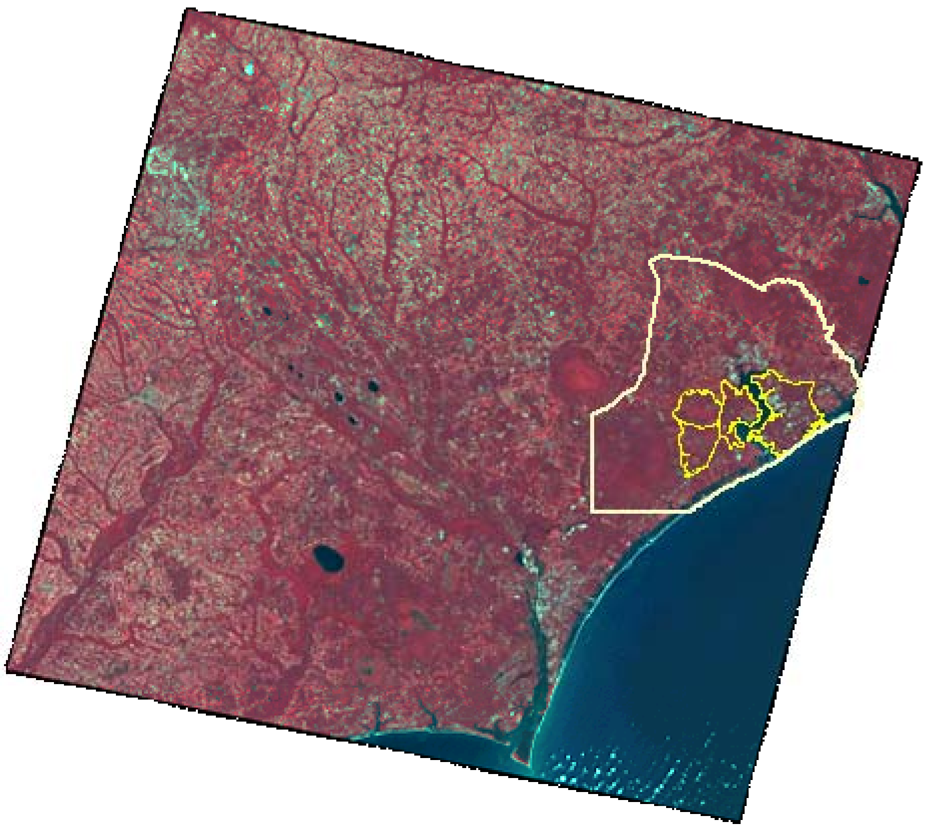


Figure 3. NALC 1980's image with Camp Lejeune (yellow) and study region subset (pale yellow).

3 The CellPicker Procedure

General Concept

The CellPicker procedure generates land cover maps for the 1970s, 1980s, and 1990s. CellPicker has two types of input data: the NALC Triplicates and the NLCD. The "ground-truth" data are considered to be the 1990s NLCD, which are classified raster grids based on 30-m Landsat TM data. The 1980s and 1970s Land Use Data are grids derived from the NALC images. The CellPicker process attempts to find grid cells in the NALC images that have the same appearance over all three decades. Grid cells with the same appearance over three decades are considered ground truth and are given the NLCD category at the same location. The classified grids are developed via a supervised classification technique using ground-truth cells from the CellPicker process.

It should be noted that the NLCD was derived from the same images that were the base for the 1990s NALC. If generated, then, the data for the 1990s NALC and NLCD are not independent. In this report, the Camp Lejeune region is used as an illustration (NALC PathRow 1536). Depending on a user's particular resource configuration, these steps may vary. This description is derived from the "Sandhills Data CDROM" (Lozar et al. 2001a) but modified to reflect more recent advances.*
The software and procedure are still under development, so this may be considered a "Beta" release description.

* This software is written in Java, and works for JDK versions 1.2.2 and later. The software is part of the Research Geographic Information System (RGIS). RGIS is a public domain GISystem designed by Dr. Charles R. Ehlschlaeger as a research and educational tool. RGIS is used in Hunter College's geographic applications programming class to demonstrate object-oriented programming and GIScience theory. This software is freely usable for research and educational purposes. Contact C.R. Ehlschlaeger for permission to use for other purposes. Use of this software requires appropriate citation in all published and unpublished documentation. Some of this software requires extensive testing before it can be considered bug free (this is version 0.2). email: chuckre@comcast.net URL: http://geo.hunter.cuny.edu/~chuck/

As described in Chapter 2, this procedure requires ERDAS Imagine 8.4 or later, ESRI ArcView 3.2 or later with Spatial Analyst Extension 2.0, and command line Java Runtime Environment 2.0 or later.

Step 1: The Creation and Preparation of Unsupervised Classification Images for Cell Picker

1. Import original NALC Triplicates into ERDAS Imagine Version 8.4. Using the Import/Export Tool on the ERDAS Main Tool Bar, import all the *.DAT Files provided by the USGS EROS Data Center. Place the imports into a folder labeled Nalcs_originals, using the nomenclature pathrow_decade. You will also need to retrieve file inputs. For import they are located in the *.DDA files provided by the USGS EROS Data Center. These inputs include:
   a. Data Type equals BSQ Unsigned 8 Bit
   b. NL equals Number of Rows and NS equals Number of Columns and NB equals the Number of Bands in each Image. (The import can be batched.)

2. Define the Newly Imported Image in ERDAS Imagine. In a Viewer, open a Raster Image, and then Click on Tools, Image Information. First Edit, Change Map Model using the following inputs:
   a. Pixel size is 60 m.
   b. Projection is UTM.
   c. UleftX equals the second UL Number and UleftY equals the first UL Number are found in the *.DDA file provided by USGS EROS Data Center. The UleftX and UleftY are in decimals in the *.DDA files, so the user must convert the exponents to real numbers.

3. ERDAS Imagine will be used to create unsupervised images. The Classifier Tool houses the classification tools, including the Unsupervised Classification tool that will be used to conduct an ISODATA-based Classification technique. First select the original image, then select the name of the unsupervised image you will create. Next choose the number of classes to create. We have chosen 100 classes. Ten iterations will increase accuracy of class grouping. Each Unsupervised Classification in Imagine takes 5 minutes per iteration. An output signature set is not necessary. Save these files as *.IMG files.

4. The final defining step is to Change the Projection. Go to Edit, Add/Change Projection. Make sure the projection is UTM Zone 18 NAD83 as noted in the *.DDA file. (Make sure that the UTM Zone has not changed when conducting a regional project.) If the image is stored in another zone, the data must be re-

projected. Use the ERDAS Data Prep Tool, once again selecting the ReProject Button. When it opens, input the following:

a. Input Project File is the NALCs Original (pathrow_decade.img).
b. Output Project File is (pathrow_decade_p.img) P=projected.
c. Select the Project Type: UTM Clarke 1866.
d. Select the UTM Zone (check this in the *.DDA files).
e. Units equal meters.
f. Accept all other defaults by clicking OK.

Note the images that are projected so that the correct image is used for subsets.

5. Subset the Image so that no header text is present on the images. This can be done in ERDAS Imagine using the Data Prep Tool located on the ERDAS Main Tool Bar. Once Data Prep is up, locate the Subset Tool and open. Once this is done, to subset an image, you need the following inputs:
   a. Input File equals the NALCs Original Image (pathrow_decade.img).
   b. Output File Equals the Subset Image (pathrow_decade_sub.img).
   c. From Inquiry Box, select the Number of Bands being displayed. This research only uses bands 2, 3, and 4. Thus, use record 2:4. (To define the subset region, a View must be open and the input image open. From Utility Menu, select Inquiry From Box making a box around the data, then press Apply so that the coordinates are recorded. Next click From Inquiry Box on the Subset Tool.)

6. ERDAS Imagine will be used to create unsupervised images. The Classifier Tool houses the classification tools, including the Unsupervised Classification tool that will be used to conduct an ISODATA-based Classification technique.
   a. First select the subset image
   b. Select the name of the unsupervised image you will create (pathrow_decade_uns.img)
   c. Select the Signature Name (pathrow_decade_uns.sig)
   d. Choose the number of classes to create. We have chosen 100 classes (Figure 4).
   e. Choose the iterations. We chose 10 iterations with a threshold of .95 Confidence, which increases accuracy of class groupings. Each Unsupervised Classification in Imagine takes 5 to 10 minutes per iteration.

7. In Imagine (version 8.4 or later), edit the Signature Files from the Unsupervised Classification to "Two Standard Deviations of the Mean." This can be done using the Classifier Tool, Signature Editor. Open the Signature File by clicking on the File Menu, Open. Next, view the statistics of the signature classes by clicking on View, Columns.

a. Select the Statistics button, turn on the Mean, Standard Deviation, Low and High Limits, and Apply. (Now you can see the Statistics columns in the Signature Editor.)
b. To conduct a classification using Two Standard Deviations of the Mean, you must select Low and High Limits to all the signature classes. To do this, Select Edit, Parallelpiped Limits. Select the Set Button.
c. Choose a Method of Limits Standard Deviation.
d. Set the value to 2.00.
e. The changes should affect all signature classes, so select the All Toggle button, then Apply.
f. Now conduct a Supervised Classification from the Signature Editor, Classify Menu. When the Supervised Classification pops up, select the following inputs:
   (1) Select an Output File (pathrow_decade_rerun.img).
   (2) Select the Parametric Rule called Parallelpiped.
   (3) Chose the Unclassified method for the Overlap Rule.
   (4) Chose the Unclassified method for the Unclassified Rule.

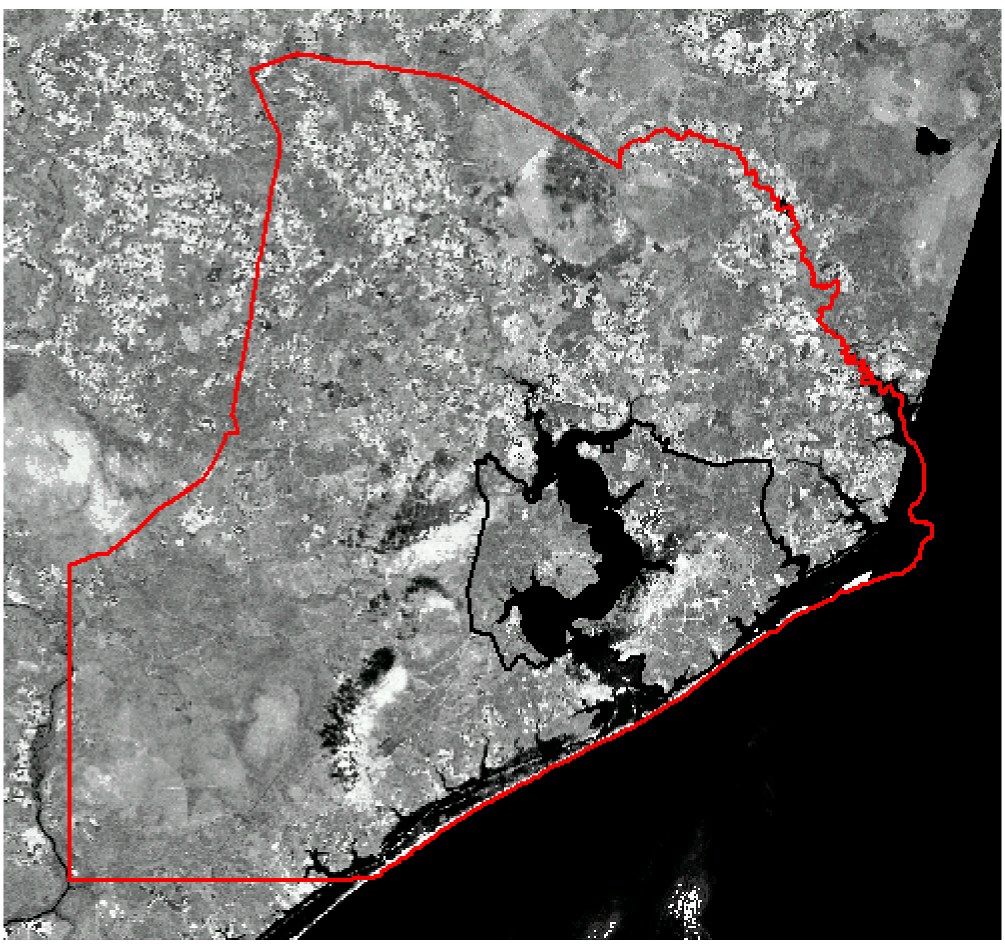


Figure 4. Unsupervised classification on the 1970s imagine into 100 classes.

8. Get grids ready for CellPicker. Export the IMAGINE Files into GRID using the Import Tool in ERDAS Imagine. When opened,
   a. Select the Export Toggle button, with type set to GRID. The Media setting is File.
   b. The Input Image is the Unsupervised Image.
   c. The output grid is (pathrow_decade_g). Press the OK button, use the defaults in the next box, and press OK.

9. Bring the Grid into ArcView. First, look at the unsupervised grid to determine if any zeros exist in the grid. If so, use the classeszerotond100.avc, which is a reclassification converting zeros to "no data." Save the newly reclassified grid by selecting the Theme dropdown menu, Save Data Set. Place these grids in a new folder with the following nomenclature: pathrow_decade_nd.

10. The last step is to make sure the data are ready to be placed in a common folder as ASCII Grids. To create ASCII Raster Grids, use ArcInfo for Batch Export Capabilities.
    a. Open the ArcToolbox in ArcInfo Version 8.0.
    b. Using the Conversion Tools, go to the Export from GRID, then click on tool Grid to ASCII Wizard.
    c. Select an Input Grid, Grid Item, and Output File Name, then hit batch to do more than one grid. You will see all the grids you have selected. You can select more than one grid by placing all the grids in the same folder, clicking the top grid name and, while holding down the shift key, clicking on the last grid name you want. Once this is done, all the highlighted grids will be batch processed.
    d. The item is the VALUE. Once you have selected all the input files, you must go down the list and type in output file names.

Step 2: The Creation and Preparation of NLCD Grids for CellPicker

1. Use the NLCD set from the USGS website http://landcover.usgs.gov/mrlcreg.html. Download the States NLCD grids that will be used in CellPicker. To download, click on the state needed. If it is only a preliminary product, that is sufficient. Click on the File Transfer Protocol (FTP) download 8-bit file. When you click on this link you will end up at the FTP site called http://edcwww.cr.usgs.gov/pub/data/landcover/states/. Now you must download the three files associated with that state dataset. Texas and California are too large and had to be broken into smaller sections. Place the files into a folder labeled NLCDs.

2. Unzip the NLCD by double clicking on the State Zip File. Once unzipped, place it in the same folder as the zip file and the other two files. Next, rename the file from *.BIN to *.BIL.

3. Create an *.HDR file using the notepad or text editor software. The following is an example of the *.HDR file used in the Sonora Project. The *.HDR file should have the same name as the *.BIL file.

```
BYTEORDER M
LAYOUT BIL
NROWS 21277
NCOLS 20583
NBANDS 1
NBITS 8
SKIPBYTES 0
ULXMAP -1233900
ULYMAP 1629780
XDIM 30
YDIM 30
```

4. Create a Grid using ArcInfo Toolbox. Open Toolbox to Conversion Tools and select Import to Grid, then click on the Image to Grid Wizard. Select input image, navigate to the *.BIL file, and click OK. Select the Band (NLCDs have only one band). Then select and output Grid Name. The naming conversion used in this Project: State initials followed by an underscore and projection abbreviation (example: nm_alb).

5. Projections and their Abbreviations used to get to the UTM Zone 18 NAD 1983 Projection:

   (alb = ALBERS)
   (dd = Decimal Degrees)
   (utm = UTM and Zone XX NAD 83)
   (utm83 = UTM 83 Zone XX)

6. Re-project the Grids to match the dataset's projection. Use the Grid Re-Projector Extension, which is downloadable from the ESRI Sample Scripts Website. Make sure the Extension is checked on in the ArcView project by going to File, Extensions, and determining that a checkmark is located beside the Grid Projector. Set the View Units to Meters and add the State_alb Grid to the View. Using the Grid Projection Tool, enter an Input Projection. NLCDs are stored in the ALBERS EQUAL AREA CONICAL. Then toggle the Input Parameters to CUSTOM. Change the Spheroid to read GRS 80 (note this datum is NAD 83). Fill in the other parameters using the state's .txt file, which was one of the

original three files that you downloaded. Albers distance is Meters. Set output parameters to Decimal Degrees.

7. The Pathrow NLCD Grids will be saved for later use; call them pathrowNLCD.

8. Next is the Class Generalization Process. NLCDs have 21 classes. Due to constraints of the MSS 1970s and 1980s images, class generalization was deemed the best approach. The classes were changed using the reclassifications in Table 1. This generalization is accomplished using the Spatial Analysis Tools in ArcView call Analyst, Reclassify Tool. Use the generalized classes in Table 1 and create a new grid called pathrow_90g_lu (generalized land use). Save the grid noting that it is generalized.

Table 1. Relation of NLCD classes to CellPicker generalized classes.

Num	Ncld_class	Numg	Generalize
11	Open Water	11	Water
12	Perennial Ice/Snow		NA
16	Marshes and Swamps	16	Marshes and Swamps
21	Low Intensity Residential	21	Low Intensity Residential
22	High Intensity Residential	22	High Intensity Residential
23	Commercial/Industrial/Transportation	23	Commercial/Industrial/Transportation
31	Bare Rock/Sand/Clay	30	Barren Lands Class
32	Quarries/Strip Mines/Gravel Pits	30	Barren Lands Class
33	Transitional	33	Transitional
41	Deciduous Forest	40	Forest/Wetlands/Parks
42	Evergreen Forest	40	Forest/Wetlands/Parks
43	Mied Forest	40	Forest/Wetlands/Parks
51	Shrubland	50	Shrublands/Grasslands
61	Orchards/Vineyards/Other	80	Agriculture
71	Grasslands/Herbaceous	50	Shrublands/Grasslands
81	Pasture/Hay	80	Agriculture
82	Row Crops	80	Agriculture
83	Small Grains	80	Agriculture
84	Fallow	80	Agriculture
85	Urban/Recreational Grasses	40	Forest/Wetlands/Parks
91	Woody Wetlands	40	Forest/Wetlands/Parks
92	Emergent Herbaceous Wetlands	40	Forest/Wetlands/Parks

9. The last step is to make sure the data are ready to be placed in a common folder as ASCII Grids. To create ASCII NLCD Raster Grids, use ArcInfo for Batch Export Capabilities. Open the ArcInfo Toolbox. Using Conversion Tools, go to Export from GRID. Click on Grid to ASCII Wizard. Select an Input Grid, Grid Item, and Output File Name, then hit batch to do more than one grid. You will see all the grids you have selected. You can select more than one grid by placing all the grids in the same folder, clicking the top grid name and, while holding down the shift key, clicking on the last grid name you want. Once this is done, all the highlighted grids will be batch processed. The item is the VALUE.

Step 3: Using CellPicker To Build a Training Set

CellPicker is a set of programs written in the Java programming language. To compile Java for your machine, open a command (DOS) window. In the command window, change to the directory where all the code exists and run the command:

```
javac.exe *.java
```

ASCII ESRI grids of both the NALC decades and NLCD should be in the same directory as the Java *.class files. For this project, there are three programs to determine which cells have not changed over the course of the three decades. The first program, GridNoDataCrop, finds the smallest rectangular bounding box around actual data for each ESRI ASCII grid passed to it as an argument. GridNoDataCrop, when used as an application from the command prompt, returns a raster grid with the same name except for a "c" at the beginning. For example, giving 1536nlcd as an argument will create the grid c1536nlcd.asc.

The second program, ThreeByThreeFilter, finds the subset of NLCD grid cells that have the same land cover values in all adjacent cells. This process ensures that minor rectification errors do not reduce the quality of the supervised classification. Finally, SupervisedCellPicker5 creates a training set (s1536nlcd) from the NALCs and NLCD (Figure 5). The Java commands are as follows:

```
java -mx512m ClassCrop PPRR_70 cPPRR_70
java -mx512m ClassCrop PPRR_80 cPPRR_80
java -mx512m ClassCrop PPRR_90 cPPRR_90
java -mx512m ClassCrop PPRRnlcd cPPRRnlcd

java -mx1024m ThreeByThreeFilter cPPRRnlcd fPPRRnlcd 6 >
fPPRRnlcd.txt
```

java -mx1024m SupervisedCellPicker5 sPPRRnlcd fPPRRnlcd cPPRR_70 cPPRR_80 cPPRR_90 > sPPRRnlcd.txt

Where PPRR is the pathrow numbers. For example, the pathrow 1536 would use the following Java commands:

java -mx512m ClassCrop 1536_70 c1536_70
java -mx512m ClassCrop 1536_80 c1536_80
java -mx512m ClassCrop 1536_90 c1536_90
java -mx512m ClassCrop 1536nlcd c1536nlcd

java -mx1024m ThreeByThreeFilter c1536nlcd f1536nlcd 6 > f1536nlcd.txt

java -mx1024m SupervisedCellPicker5 s1536nlcd f1536nlcd c1536_70 c1536_80 c1536_90 > s1536nlcd.txt

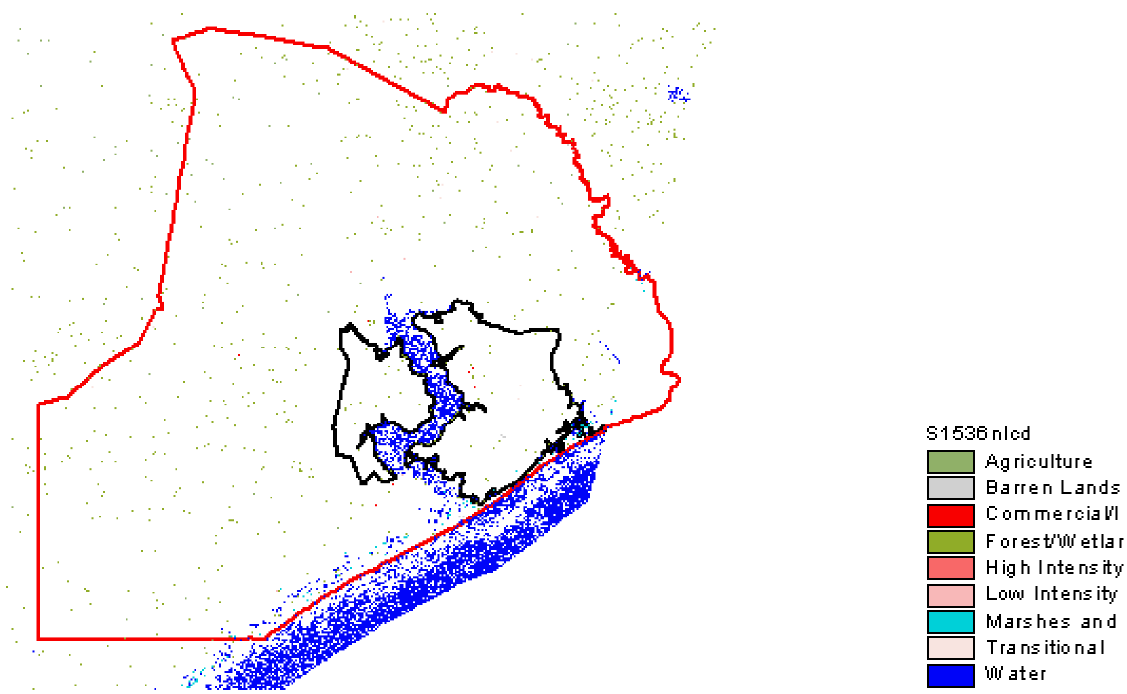


Figure 5. The CellPicker supervised (s1536nlcd) file — it is expected to be sparse.

Step 4: Importing the Training Sets To Create Imagine/Grid Files for Supervised Classification

1. Create a folder called trainingpixels. This will be where the grids and Imagine files are placed. Use ArcView to import the training sets. In ArcView, go to File/Import_Data. When the wizard opens, select ASCII Raster and find the input file located in /derivedlanduse folder, s*PPRR*nlcd.asc, where *PP* is the path number and *RR* is the row number. The output file name should be the same as the ASCII file's name. For example, use s3538nlcd as the grid name if s3538nlcd.asc is the ASCII grid file. The cell values are integers. Add the grids to the view.

2. Now bring grid(s) (s*PPRR*nlcd.asc) into Image BIL files using ArcInfo. Start the ArcInfo ToolBox and look for the GRID to Image Tool. The input file is the training set grid (e.g., s1536nlcd), the image type is BIL, and the output file is called t_PPRRbil.bil. This creates the Imagine files needed for retrieving the signatures.

3. Now check the BIL files in Image Information from the Tools menu located within the Imagine Program Bar. First open the BIL file, then Go to "Edit, Compute Stats." Change the map model with "Edit/Change Map Model" so that it reads UTM and meters. Fix the projection with "Edit/Change Projection" to read WGS 83, Datum: WGS 83, Appropriate Zone 18 (for Camp Lejeune).

Step 5: Creating Signature Files for Supervised Classification

1. Create the Signature files from the training sets. Use the Signature Editor Classifier located on the Main Tool Bar. Once the Signature Editor is open, select Edit/Image Association. Set the associated image name for a decade as the subset image.

2. Use the BIL file to extract signatures from the SUBSET Image. From the Edit Menu, select Extract from Thematic Layer (these are the training datasets saved as Imagine files). The Input Thematic File is the training BIL Image (pathrow_t.bil). The output file will be the signature file named pathrow_decade_t.sig. (The signatures should be placed in the training sets folder.) The Signature editor main menu will look like nothing is loaded, but the process will run. The Signatures are created from the subset images' statistics. The training data sets represent pixels that have not changed over the three decades. Those pixels are referred to as ground-truth data. Next the new signatures of each subset image can perform a supervised classification.

Step 6: Creating and Finalizing Supervised Classifications

1. To create supervised classifications, you need signatures and subset images. Open the Classifier from the main tool bar in ERDAS Imagine. Click on the Supervised Classification button. The Input Image is the subset image (pathrow_decade_sub.img). The Signature File is the training signature file just created (pathrow_decade_t.sig). The output is the supervised classification image: pathrow_decade_s.img.
   a. Now choose a Non-parametric Rule from the drop down menu called None. Choose Parametric Rule: Minimum Distance. Then click the Batch button if you plan to do more than one supervised classification. Name the files pathrowdeacdeg_lu.
   b. Experiment with several different methods of Supervised Classification to determine which output provides the best results. For the Sandhills dataset, the minimum distance supervised classification technique was used.

2. Export from Imagine images to ArcView grids. Use the Export Tool in ERDAS Imagine. Create a folder called supervised_mindist/supergrids in which to place the grids.

3. Once the data is in ArcView GRID Format, load the grids into an ArcView project. View the grids to see whether they overlap properly (Figure 6).

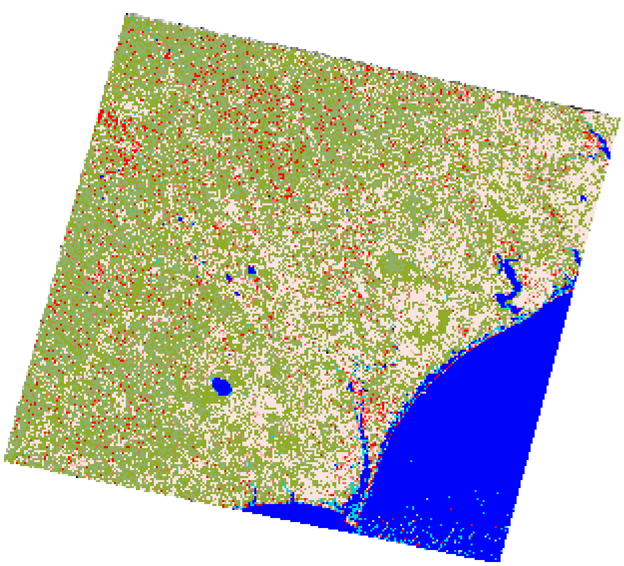


Figure 6. Supervised classification resultant grid for 1980s image (1536_80_s).

4. The supervised grids are finalized by adding the training sets to them. To do this, the user will take the training data set (/trainingpixels/sPPRRnlcd from the SupervisedCellPicker5 Java script run) and the co-existing pathrow of the three supervised classifications from paragraph 1 above. In ArcView 3.2, open a View and place the four grids into it. Adjust the Analysis Properties so that the extent is set to View, the cell size is “As Value Below,” 60 meters, and the Mask is set to the pathrow_80. For the Sandhills dataset, the decade of the 1980s is always the largest data set.

5. Next make training set grids (sPPRRnlcd) with “No data” as zero and a Binary Data Set with data as zero, and “No data” as one. This will be used later in the Map Calculation Step. If the entire area you want to calculate is not represented by data, the Map Calculation will cut off the data where No Data begins. Remember, the 1970, 1980, and 1990 images vary in size.
    a. Make “No data” to zero using the Analysis, Reclassify tool. Save this new grid in /trainingpixels/nd2zero.
    b. Make the binary data grid from the previous step’s grid. To make the binary grid, select Analysis Properties/Reclassify. Change all the data values 11- 99 to 0s, 0 to 1, and the no data to 1. Save this binary grid to /trainingsets/binaries.

6. Open the Map Calculator Tool located in Analysis Properties. Add the training sets data to the supervised classification grids. For each Pathrow_decade run the following map calculation and then save the file to /supervised_mapcalc. The Map Calculator Formula is:

    ([binary grid] * [Supervised Grid] + [nd2zero grid])

    For example: ([B1536]* [s1536_90]+ [nd2zs1536])

7. Make sure the newly created map calculations are saved. Reclassify the grids so that the zero class is removed. Call the final land use maps: pathrow70g_lu (generalized land use) and pathrow80g_lu (see Figure 7).

8. Convert the grids pathrow70g_lu and pathrow80g_lu back to ASCII files with the names PPRR70.asc and PPRR80.asc for each pathrow.

9. Convert the grids pathrow_90g_lu back to ASCII files with the names PPRR90.asc.

10. Run the Java program FixGenLU to perform the following classifications in order to improve the quality of CellPicker.

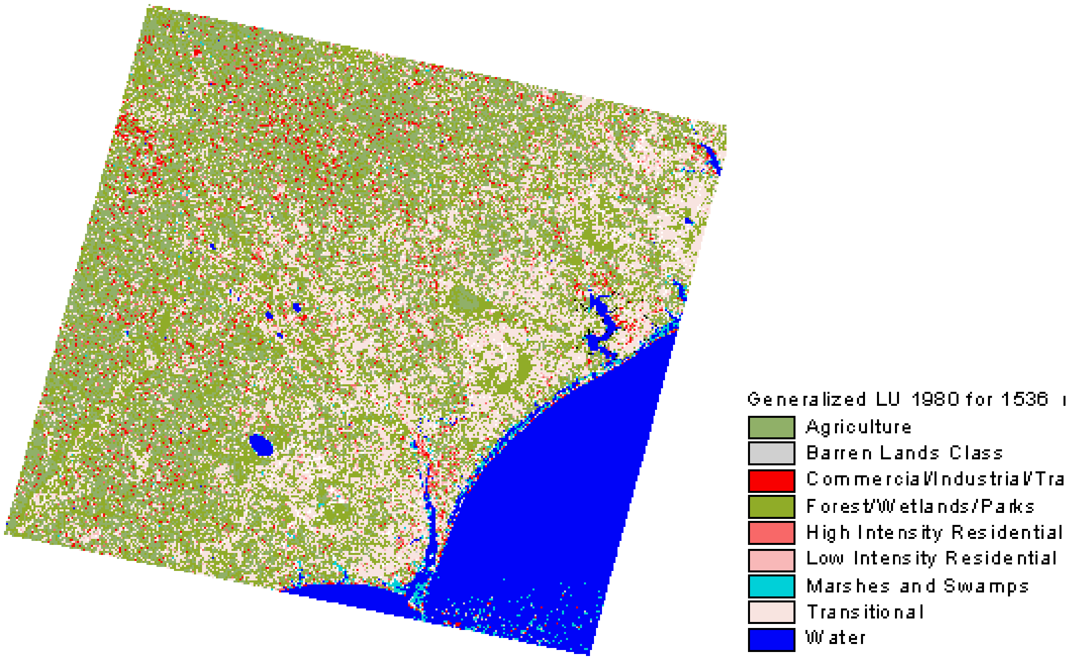


Figure 7. Generalized land uses from the 1980s image covering all of the 1536 area.

a. Open water (category 11) must exist in the NLCD to be considered open water in the derived land use maps. This minimizes problems caused by streaks in original NALC Triplicates.

b. Commercial and industrial (category 23) must exist in the NLCD to be considered commercial and industrial in the derived land use maps. This minimizes mismatches.

c. Medium intensity residential (category 22) must exist in the NLCD as category 22 or category 23 to be considered medium intensity residential in the derived land use maps.

d. Low intensity residential (category 21) must exist in the NLCD as categories 21, 22, or 23 to be considered low intensity residential in the derived land use maps.

Once again, the ASCII grids of the three decades should be in the same directory as the Java class files (Figure 8).

Example runs for the 1536 pathrow are:

```
                         {earlier   nlcd   output}
java -mx512m FixGenLU 153670 153690 153670n
java -mx512m FixGenLU 153680 153690 153680n
java -mx512m FixGenLU 153690 1536nlcd 153690n
```

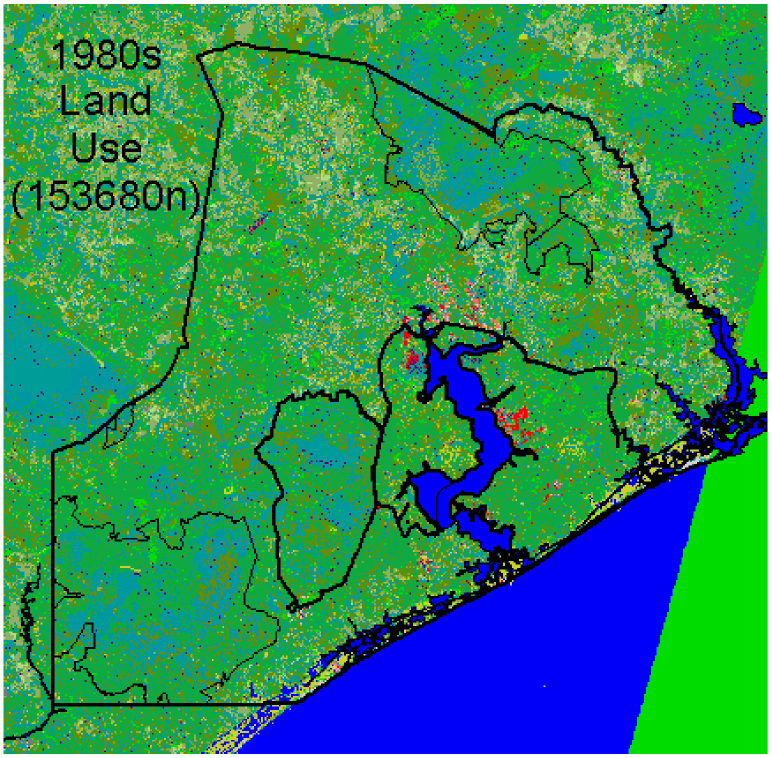


Figure 8. Result of FixGenLU for 1980s (153680n) in the study area.

11. Run the Java programs ConfusionMatrix and CellPickerError to create confusion matrices to calculate relationships between generalized landcover maps with original NLCDs as well as calculate the estimated errors of the CellPicker process via cross-validation.

Example runs for the 1536 pathrow are:

java -mx1024m ConfusionMatrix 153690n 1536nlcd 153690n > 1536n.txt

java -mx1024m CellPickerError 153690n 1536nlcd s1536nlcd 1 > 1536est.txt

12. Convert the generalized landcover grids PPRR70n.asc and PPRR80n.asc back to Grid format (Figure 9).

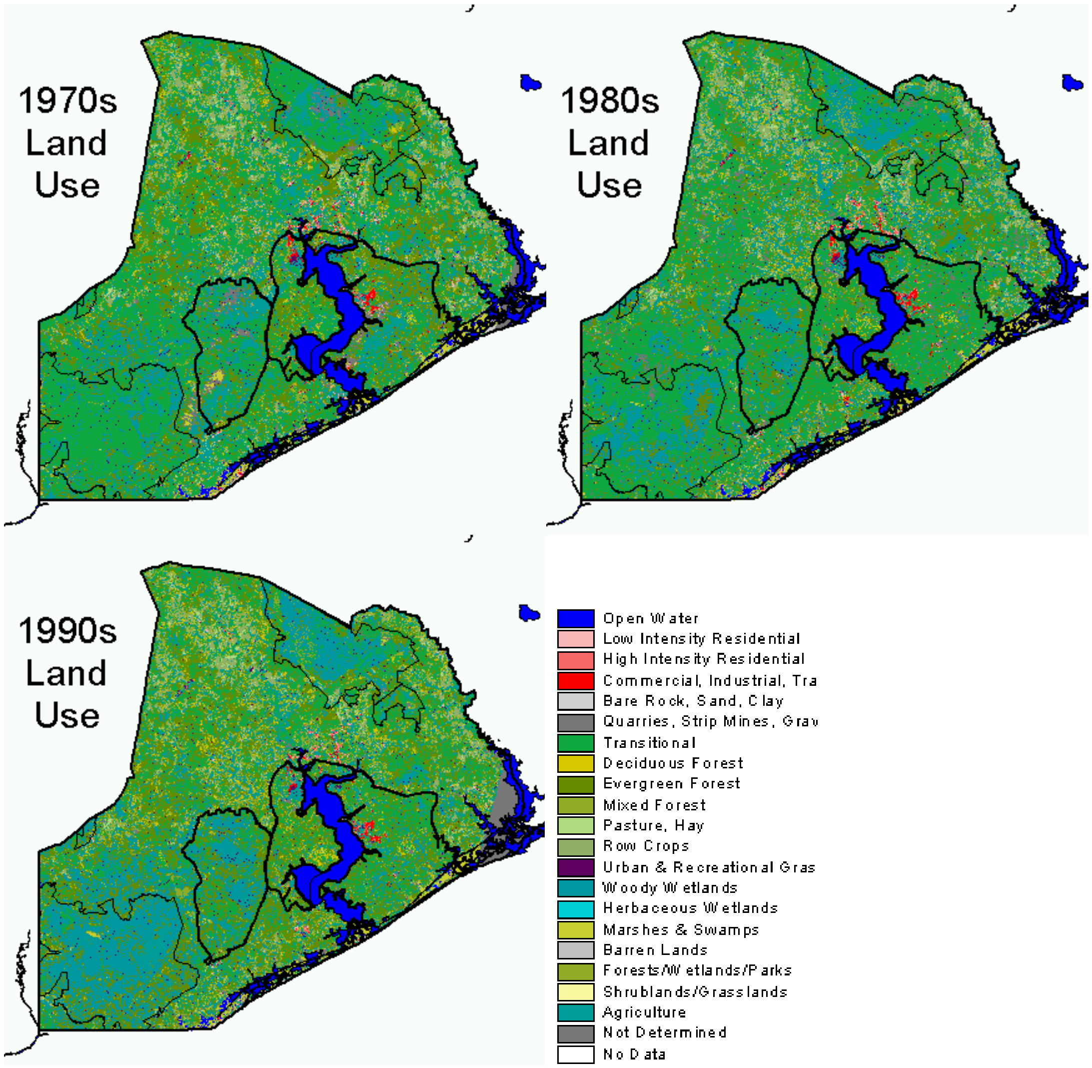


Figure 9. Land use for each decade as determined using the CellPicker Method.

4 Integrating Other GIS Data With CellPicker Results

A historical growth presentation is incomplete with only the results of the CellPicker procedure. Normally, four primary sources of data are combined:

- contextual data
- parcel information
- other mapped sources
- CellPicker results.

The first set is the general contextual data, much of it available via the Internet. Vector files can be acquired from ESRI, USGS, and the Online National Atlas.

Second, parcel data shows the areal extent of the land upon which development occurs. The data may be acquired from county and municipality offices. Knowing a parcel has structures built on it is important. Often one of the fields within the parcel information indicates when a taxable structure was built. Although this may be no more than a shed, it is more commonly a residential or commercial structure. It indicates activity and a significant financial investment that might be in conflict with the installation's training missions. On the other hand, a parcel without a taxable structure is less likely to present a conflict to the installation. Although this assumption may sometimes be incorrect, on the whole it will well represent the general pattern of development, and that is what we are looking for. So using the ArcView select and save procedure, extract parcels upon which it is indicated that a taxable structure was built during each decade. The implication is that that parcel of land is likely to be used for a more active purpose (e.g., residential or commercial usage).

Third, historical maps or orthoquads can be referenced. The general concept here has already been described (Timlin et al. 2002). In a GIS-based initiative, once the maps are acquired they need to be scanned, geo-referenced, and digitized to fill in missing information. This is particularly important for portions of a study area where parcel data are not available. Once in place, scanned images can be examined for areas that indicate development or land changes, particularly clearing of land. Some forest clearing practices can be confused with development; however, if cleared areas are distant from other development and roads, it is likely the activity

is forestry-related rather than development. Another clue to distinguish forestry activity from development is that, over the decades, the forestry-cleared areas grow back while development areas slowly expand. Derived data can be reformatted to make it compatible with the county and city parcel data. This work results in a series of files illustrating each decade's land ownership changes (Figure 10).

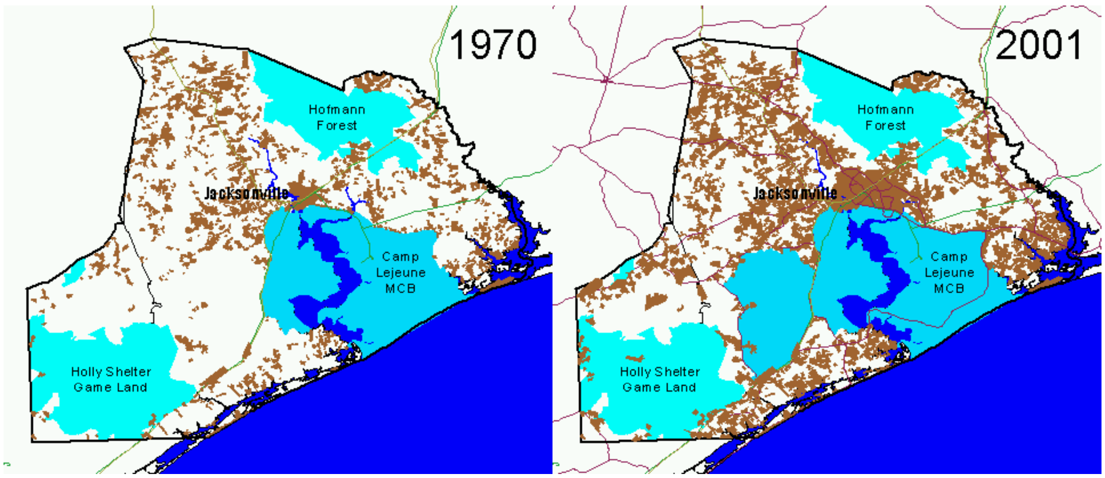


Figure 10. Examples of the growth through identification of parcels with built structures.

Fourth, the data used up to now show the expansion of land upon which a structure was built, but does not show the intensity of the use of that land. For this purpose, the results of the CellPicker process on the NALC images are used. Figure 9 shows the results for each decade (at 60-m resolution). Figure 2 shows the NLCD set (at 30-m resolution) to which they are compared and which is used to derive the decade land uses.

After the CellPicker process is complete,* those categories that implied an active use that is likely to generate an incompatibility with installation training, testing, or readiness missions (particularly noise) are extracted. For encroachment purposes, the categories of most interest are 21 – Low Intensity Residential, 22 – High Intensity Residential, and 23 – Commercial/Industrial/Transportation. (Although industrial and transportation might not be considered incompatible uses, previous examination of the data has indicated that most of the pixels represent the commercial segment.) Since the images show built structures, the owned/used land associated with the structures have to be more extensive. Therefore, the cells of each land use type are expanded to the size of a standard lot (roughly 90 m) so that

* Chapter 5 discusses the statistical evaluation (for each decade of land uses generated from the images for each of the land use types) of the "goodness" of fit and means for improving that fit.

likely associated land would be included. These three sets are then merged together. In locations of overlapping sets, the priority might be:

1. High Intensity Residential
2. Commercial
3. Low Intensity Residential*

For the purposes of encroachment illustrations, the data derived from the CellPicker process are used to indicate intensity of usage. However, since we wish to deal only with parcels known to be built on (that is, the intensity of use data was not to go beyond the built-on parcel locations), the intensity of use levels can be clipped off at the parcel edges. Of course, intensity of use data starts with the 1970's image. It is a good idea to check the intensity of use results against any available USGS maps for your study area. On the USGS maps, the distributions of building densities and their locations will help to confirm the generated distributions.

The most impressive means to see the trends over time is to animate the individual decade results. Individual images, such as those in this report, are not nearly as powerful. Microsoft® PowerPoint® has an animation capability. On the PowerPoint "Slide Show" menu, access the "Custom Animation" option. Within the Custom Animation box, each *time period* (e.g., decade) is an *object*. Set the earliest frame to *Object 1*, next to *Object 2*, etc. Reasonable tab settings are *Start Animation automatically*, *first slide appears*, *the rest "dissolve"* into the screen *every 2 seconds.* If you have PowerPoint, and are viewing this document online, double click on Figure 11 for an example presentation.

* There is the suggestion that the *Low Intensity Residential* category is the highest sensitivity and therefore should be first in priority. The priority depends on whether the *Low Intensity* category consists mostly of high or low cost housing. If it is mostly lower cost, *then Low Intensity* should be priority 3. It depends on the character of your study area.

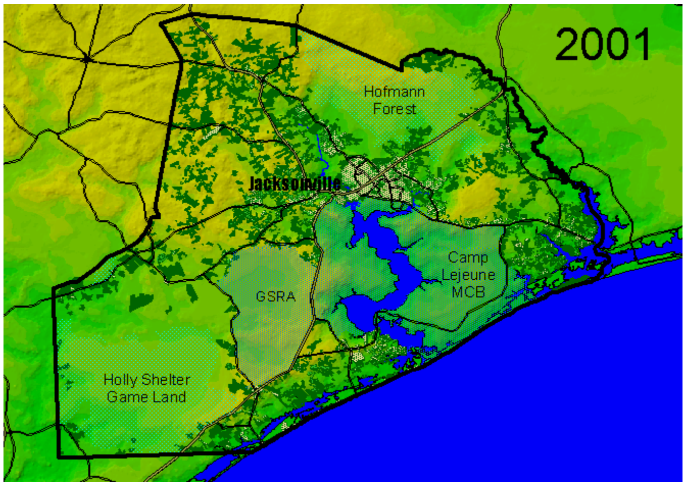


Figure 11. Example animated presentation. If you have MS PowerPoint, double click on the figure.

5 Interpretation and Enhancement of the CellPicker Accuracy

Interpretation

The CellPicker Java program called ConfusionMatrix (described near the end of Chapter 3) is used to calculate the relationship between generalized land cover maps derived from CellPicker with the original NLCDs. A confusion matrix is a way to examine the performance of a classifier procedure. It contains information about actual and predicted classifications done by a classification system. Performance of such systems is commonly evaluated using the data in the matrix. The accuracy is the proportion of the total number of predictions that were correct. The ConfusionMatrix Java program compares the generalized NLCD categories against the original categories for the 1990's decade, which, within this procedure, are assumed to be ground truth. The appendix provides an illustrative example of a confusion matrix for the Camp Lejeune data comparing the 1980's image-derived land uses versus the NLCD. The example results show actual categories in the left column and predicted categories in the row headers. The table is folded (i.e., two lines per row). The best situation is a 100 percent identification (1.00000) as at the intersection of category 11 with 11 (Open water VS water). The ratio of "correct hits" for category 21 "Low Intensity Residential" to itself was almost 85 percent (0.84367). An 85 percent correct identification is very good. (In fact, in generating the NLCD, USGS only guarantees an 85 percent correct identification.) The procedure confused category 21 with category 22 "High Intensity Residential" about 5 percent of the time (0.04585) and category 23 "Commercial/Industrial/Transportation" about 11 percent of the time (0.11048). There are no mistaken identifications with the other categories (0.00000). In fact, these values reflect the common sense notion that Low Intensity Residential, High Intensity Residential, and Commercial/Industrial/Transportation are more similar than forest, agricultural, or swamp land. The rest of the data may be interpreted similarly.

The bottom line labeled "G1Ratio" represents the column's proportion of the study area. The right column labeled "OnRatio" is each row's proportion of the study area.

The CellPickerError Java program also generates a report of a similar format. CellPickerError is nothing more than ConfusionMatrix with the ability to declare a "no data value" in its command line.

Revision Options To Improve Results

Sometimes the ConfusionMatrix results can be improved. The CellPicker process is often repeated 3 to 4 times, modifying parameters or ERDAS options each time to generate useful results. If these look good, then you are on the right track. Some variations that can be useful include:

- When doing the supervised classification (Step 6, part 1.b), try using different methods to see which works best
- Change the parameters in Step 1, parts 6.d and 6.e.

The good news is that, once a process for a particular pathrow is found, those other pathrows with similar vegetative and geologic characteristics will work with the same parameters.

6 CellPicker Limits

All RS manipulations have limits to the quality of their identification. Unlike many other procedures, however, CellPicker provides a good deal of backup statistical evaluation so that an individual can objectively see how good the data are. This chapter documents known concerns that limit the reliability of the data and how the limitations were minimized.

The original NLCDs claim 85 percent accuracy against reality. Since CellPicker attempts to replicate NLCD data in earlier decades, even a perfect fit will be only 85 percent accurate.

To minimize some of these issues, several assumptions were made within the CellPicker Java software:

- Open water (category 11) must exist in the NLCD to be considered open water in the derived land use maps. This minimizes problems caused by streaks in the original NALC Triplicates.
- Commercial and industrial (category 23) must exist in the NLCD to be considered commercial and industrial in the derived land use maps. This minimizes mismatches.
- Medium intensity residential (category 22) must exist in the NLCD as category 22 or 23 to be considered medium intensity residential in the derived land use maps.
- Low intensity residential (category 21) must exist in the NLCD as category 21, 22, or 23 to be considered low intensity residential in the derived land use maps.
- The original NLCD categories were compressed to a reduced number to better classify land cover due to the lack of ground-truth land use data.
- With no actual ground truth, the Confusion matrices were run on the 1990s NALC images as well as the 1980s and 1970s NALC images in order to perform cross-validation. By comparing cells not found by the CellPicker process in the 1990's NALC image with the NLCD, how error prone the model is can be estimated. Confusion matrices comparing the 1990 derived land use categories against the combined NLCD categories can be generated. These confusion matrices, assuming the 1970 and 1980 image is as clear as the 1990 image for that pathrow, should provide a good estimate of that pathrow's accuracy.

- A final step was performed if the 1990s NLCD class at a cell was a possible actual class. Generalized classes in the 1970s and 1980s land cover grids were converted to the original NLCD classes. For example, suppose a cell in the 1970s grid contained class 40, which generalizes all NLCD forest classes. If, at that location, the NLCD grid contains deciduous forest, the 1970s grid cell is given the deciduous forest class. This assumption will be correct most of the time. It is possible, however, that an evergreen forest existed at a location in 1970 but was actively managed to become a deciduous forest (a goal at several National Forests). Without ground-truth data from the 1970s and 1980s, it is impossible to estimate the reduction in accuracy caused by this "increase in precision."

NALC Triplicates provide only a single image per decade. A "leaf on" and "leaf off" image for each decade would provide better results. Two problems arise from using a single image:

1. It is not possible to differentiate Deciduous and Evergreen Forest. This is not a concern for encroachment studies since this category is not used.
2. Low Intensity Residential is poorly defined with only a single image. There will be more mismatches between Low Intensity Residential and various row crops or forested areas. This is a concern for encroachment studies, but can be minimized by cutting out any cells that do not have a taxable structure present, which largely eliminates row crops or forested areas.

7 Conclusions and Recommendations

Conclusions

Many Department of Defense (DoD) installations are experiencing increased pressure on their military mission activities due to the development and placement of land uses near the installation boundaries. The new land uses, often described as "urban encroachment," may in some way conflict with the ongoing activities at an installation. To deal with this issue, it is useful to clearly establish the historical urban growth trend in areas surrounding an installation. Recent advances in computer analysis techniques based on remotely sensed satellite imagery have allowed the establishment of a scientifically derived baseline for development growth near an installation.

We have described the inputs to this procedure. The first, beginning in 1972, are the Landsat satellites, which began taking images of the earth's surface. USGS and EPA have generated a three-decade series of images (called the NALC Triplicates) for the early part of the 1970s, 1980s, and 1990s at 60-m resolution. Another program generated the NLCD at 30-m resolution for the early 1990s.

As part of its ongoing research program, ERDC has supported the development of the CellPicker software package to use the NLCD as source data and derive associated land uses from the NALC images. The current version of this procedure was described in detail so that installation staff with similar resources can develop a multi-decade set of land cover data for their area. ERDAS Imagine 8.4 or later, ESRI ArcView 3.2 or later with Spatial Analyst Extension 2.0, and command line Java Runtime Environment 2.0 or later are required. Because the CellPicker procedure is largely run in a rule-based environment:

- The viability of the product resulting from this procedure can be validated statistically based on routines that are part of the package. Further, it can be statistically documented how slightly varying the inputs can improve the fitness of the result.
- Known limits to the quality of the land cover identification can be stated, and the effect they might have on a specific application (e.g., encroachment) can be minimized.

For the purposes of encroachment characterization, the land use/land cover data need to be integrated with contextual data, parcel information, and other mapped sources. A method was described for reducing and assimilating the CellPicker data into a useable, animated presentation format.

An individual following the described procedure can expect to generate three primary products:

- A set of Landsat satellite RS images (for the 1970, 1980, 1990 decades). Figure 3 is an example.
- A set of land cover GIS data showing changes in each decade (1970s, 1980s, and 1990s). Figure 9 is an example.
- A set of map-style frames showing urban growth character. The series may begin before the 1970s, depending on availability of source maps. Figure 11 is an example.

Recommendations

1. CellPicker is currently a beta version. It is recommended that further efforts continue to:
   a. Improve the software
   b. Improve the statistical evaluation (the confusion matrices)
   c. Automate the procedure.

2. The results can be used for the generation of GIS as well as an animated presentation. The full value of the decade distributions should be used to evaluate how well the installation plans are doing to mitigate and avoid off-installation potentially conflicting activities (e.g., Lozar 2003).

3. This procedure does not extend or predict future trends. The next logical step for an installation is to begin to focus efforts toward more clearly defining the direction and impacts of future growth within the region. ERDC is in the process of developing this capability for military installations and would be able to assist in this recommended step.

4. USGS and EPA are in the process of generating NLCDs for the early 2000s. If available, it would be useful to use these as additional ground truthing. If not available, it would be useful to cooperate with those agencies in getting the NLCD generated for your study area.

References

Cowardin, L.M., V. Carter, F.C. Golet, and E.T. LaRoe. 1979. *Classification of Wetlands and Deepwater Habitats of the United States*, Fish and Wildlife Service, U.S. Department of the Interior, Washington, DC.

Deal, Brian. 2001. *mLEAM: the Military Land use Evolution and impact Assessment Model*. ERDC/CERL Technical Note TN-01-2, U.S. Army Engineer Research and Development Center (ERDC), Construction Engineering Research Laboratory (CERL), Champaign, IL, ADA408969, 07 November 2001

Kelly, P.M., and J.M. White. 1993. Preprocessing remotely sensed data for efficient analysis and classification, Applications of Artificial Intelligence 1993: Knowledge-Based Systems in Aerospace and Industry, Proceeding of SPIE, pp 24-30.

Lozar, Robert, *Historical Urban Growth Trends Around Camp Lejeune, NC*. 2003. ERDC/CERL technical report (TR) (In preparation), Champaign, IL.Lozar, Robert C., C. Ehlschlaeger, and Harold Balbach. 2001a. “Remotely Sensed Temporal Land Use Data for the Sandhills Ecoregion”; poster paper presented at the Annual SERDP Symposium, Washington, DC, November 2001.

Lozar, Robert, Wade Smith, Hazekiah Adeyemi, Olayiwola Taylor, Renee Jacokes, M. Norman Malinas, Musa Danjaji, Tereza Flaxman, and Allan Shearer. 2001b. *A Catalog of Applications for Classified and Declassified Satellite Imagery*, ERDC/CERL TR-01-61, ADA396729, August 2001.

Rose, Winifred H., Robert C. Lozar, and Richard L. Schneider. 2000. *Scoping Report for a Scenario-Based Planning Protocol for Aplication in the Regions of Army Installations*, ERDC/CERL TR-00-39, ADA385411.

Steinitz, Carl. 1967. *Computers and Regional Planning: The DELMARVA Study*. Harvard Graduate School of Design.

Steinitz, Carl, Hector Arias, and Allan Shearer. 2002. Alternative Futures for Changing Landscapes: The Upper San Pedro River Basin in Arizona and Sonora, Island Press, November 2002.

Steinitz, Carl, Michael Binford, Paul Cote, Thomas Edwards, Jr., Stephen Ervin, Richard T.T. Forman, Craig Johnson, Ross Kiester, David Mouat, Douglas Olson, Allan Shearer, Richard Toth, and Robin Wills. 1996. *Landscape Planning for Biodiversity: Alternative Futures for the Region of Camp Pendleton, CA*, produced by the authors under work funded by the DoD/DOE/EPA Strategic Environmental Research and Development Program, and printed by the Harvard Graduate School of Design.

Timlin, Diane M., Douglas M. Johnston, and Brian M. Deal. 2002. *Guidelines for Developing Historic Urban Growth Series for Military Installation Risk Assessment*. ERDC/CERL TR-02-4, ADA408249, 26 February 2002.

Vogelmann, J.E., T. Sohl, and S.M. Howard. 1998a. "Regional Characterization of Land Cover Using Multiple Sources of Data." *Photogrammetric Engineering & Remote Sensing*, Vol. 64, No. 1, pp 45-47.

Vogelmann, J.E., T. Sohl, T., P.V. Campbell, and D.M. Shaw. 1998b. "Regional Land Cover Characterization Using Landsat Thematic Mapper Data and Ancillary Data Sources." *Environmental Monitoring and Assessment*, Vol. 51, pp 415-428.

Appendix: Confusion Matrixes From CellPicker Procedure

Example results from assigning land uses to the NALC 1980s versus NLCD categories:

cnfus	11	16	21	22	23	31	32	33	41	42	43	81	82	85	91	92	OnRatio
11	1.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.04387
16	0.30001	0.40454	0.00828	0.00241	0.01018	0.01986	0.00309	0.00886	0.02333	0.06023	0.02193	0.00716	0.03161	0.00216	0.09629	0.00004	0.00967
21	0.00000	0.00000	0.84367	0.04585	0.11048	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00237
22	0.00000	0.00000	0.00000	0.52804	0.47196	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00230
23	0.00000	0.00000	0.00000	0.00000	1.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00142
31	0.00720	0.00256	0.00016	0.00000	0.00112	0.97278	0.01377	0.00000	0.00096	0.00032	0.00048	0.00000	0.00064	0.00000	0.00000	0.00000	0.00084
32	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	1.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00050
33	0.00710	0.00568	0.01262	0.00311	0.00565	0.00085	0.00049	0.02122	0.05695	0.39366	0.06264	0.02514	0.13803	0.00172	0.26496	0.00019	0.20823
40	0.02492	0.02370	0.05711	0.01413	0.02397	0.00399	0.00207	0.04638	0.00000	0.00000	0.00000	0.12691	0.67680	0.00000	0.00000	0.00000	0.09039

```
41      0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000
1.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.03948

42      0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000
0.00000 1.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.15984

43      0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000
0.00000 0.00000 1.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.03930

80      0.01307 0.00661 0.04466 0.01943 0.03193 0.00442 0.00208 0.01538
0.16621 0.30915 0.12734 0.00000 0.00000 0.01476 0.24451 0.00044 0.08949

81      0.00004 0.00003 0.00008 0.00001 0.00007 0.00001 0.00000 0.00001
0.00168 0.00105 0.00075 0.95786 0.03740 0.00001 0.00101 0.00000 0.02376

82      0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000
0.00000 0.00000 0.00000 0.00000 1.00000 0.00000 0.00000 0.00000 0.12643

85      0.00393 0.00336 0.00193 0.00032 0.00095 0.00061 0.00011 0.00231
0.03905 0.35435 0.05330 0.00685 0.01566 0.23149 0.28579 0.00000 0.00591

91      0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000
0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 1.00000 0.00000 0.15609

92      0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000
0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 1.00000 0.00008

GlRatio 0.05171 0.00785 0.01388 0.00501 0.00908 0.00194 0.00102 0.01009
0.06671 0.27218 0.06428 0.03958 0.21764 0.00307 0.23580 0.00016
```

Acronyms and Abbreviations

ASCII	American Standard Code for Information Interchange
BIL Band Interleave	A format for storing imagery data (vs BSQ)
BIN	Binary format
BLM	Bureau of Land Management
BSQ Band Sequential	A format for storing imagery data (vs BIL)
CDROM	Compact Disk Read Only Memory
CERL	Construction Engineering Research Laboratory
CUNY	City University New York
DEM	digital elevation model
DNL	Day night noise level
DoD or DOD	Department of Defense
DOE	Department of Energy
ECMI	Ecosystem Characterization and Monitoring Initiative
EPA	U.S. Environmental Protection Agency
ERDAS	A company that makes software for Remote Sensing
ERDC	U.S. Army Engineer Research and Development Center
EROS	Earth Resources Observation Systems – a USGS data center
ESRI	A Company that makes GIS software
FTP	File Transfer Protocol
GIS	Geographic Information Systems
GRID	A format for saving GIS data in a cell form rather than line form
GRS	Grid Reference System

HDR	Header file
IMAGINE	An ERDAS software package
IMG	A format for saving imagery data
IP	Image Processing
MCB	Marine Corps Base
MRLC	Multi-Resolution Land Characteristics Consortium
MS	MicroSoft®
MSS	Multispectral Scanner
NAD	North American Datum
NALC	North American Land Characterization
NASA	National Aeronautics and Space Administration
NC	North Carolina
NLCD	National Land Cover Data
NOAA	National Oceanic and Atmospheric Administration
PPRR	Path Row designation (of the NALC data set)
RS	remote sensing
SEMP	SERDP Ecosystem Management Project
SERDP	Strategic Environmental Research and Development Program
TM	Thematic Mapper
TRMD	Training Resources Management Division (MCB Camp Lejeune)
USFS	U.S. Forest Service
USGS	U.S. Geological Survey
UTM	Universal Transverse Mercator
WGS	World Grid System
WWW	World Wide Web

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE (DD-MM-YYYY)
5-2003

2. REPORT TYPE
Final

3. DATES COVERED (From - To)

4. TITLE AND SUBTITLE
A Geographic Information Systems (GIS) and Imagery Approach to Historical Urban Growth Trends Around Military Installations

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
Robert C. Lozar, C.R. Ehlschlaeger, and Jennifer Cox

5d. PROJECT NUMBER
622720A896

5e. TASK NUMBER
DKK777

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
U.S. Army Engineer Research and Development Center (ERDC)
Construction Engineering Research Laboratory (CERL)
PO Box 9005
Champaign, IL 61826-9005

8. PERFORMING ORGANIZATION REPORT NUMBER
ERDC/CERL TR-03-9

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
U.S. Army Corps of Engineers
441 G Street, NW.
Washington, DC 20314-1000

10. SPONSOR/MONITOR'S ACRONYM(S)
CEERD-CVT

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION / AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

13. SUPPLEMENTARY NOTES
Copies are available from the National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161.

14. ABSTRACT

Recent advances in computer analysis techniques based on remotely sensed satellite images can be used with other geographic information systems (GIS) data to establish a scientifically derived baseline of growth near military installations. Developing such a trend analysis is one step in support of a military initiative to identify and mitigate pressure on its military mission activities due to the development or placement of land uses near installation boundaries. The new land uses, often described as "encroachment," may in some way conflict with the ongoing activities at an installation. This study documents a unique procedure called "CellPicker", which generates land cover changes using satellite images and contextual GIS data for the each decade beginning in the 1970s.

15. SUBJECT TERMS
Geographic Information Systems (GIS), land management, master planning, military installations, encroachment, satellite imagery, urbanization

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			Robert C. Lozar
Unclassified	Unclassified	Unclassified	SAR	46	19b. TELEPHONE NUMBER (include area code) (217)352-6511x6367